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RELEASING SOFTWOOD REGENERATION FROM OVERTOPPING ALDERS

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NEWFOUNDLAND FOREST RESEARCH CENTRE
ST. JOHN'S, NEWFOUNDLAND
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ABSTRACT

Three herbicide treatments and brushcutting were compared as means of releasing artificially-seeded black spruce (Picea mariana (Mill.) B.S.P.) and jack pine (Pinus banksiana Lamb.) seedlings from overtopping alders on a Newfoundland burned cutover. Two growing seasons after treatment, 2,4-D applied by mistblower was found to have given good control of alders with minimum regrowth and minimum damage to the softwoods. Tordon, a non-selective herbicide applied in pellet form, killed most alders and inhibited regrowth, but killed or damaged many spruce and pine. Brushcutting removed all alders but regrowth was rapid and dense, and softwood seedlings thus released suffered mechanical and physiological damage. No evidence was found of increased softwood growth rates due to release from the alders, but periodic remeasurements will be continued to determine if release growth will become evident later.

RÉSUMÉ

Pour dégager des plants d'épinette noire (Picea mariana (Mill.) B.S.P.) et de pin gris (Pinus banksiana Lamb.) des aulnes dominantes d'une région déboisée et brûlée de Terre-Neuve, on a comparé trois traitements à l'herbicide et le coupage des broussailles. Deux saisons de croissance après le traitement, on a trouvé que 2,4-D appliqué par pulvérisateur a donné un bon contrôle des aulnes avec un minimum de régénération et un minimum de dommage infligé aux conifères. Le tordon, un herbicide non-sélectif, appliqué en granules, a tué la plupart des aulnes et en a empêché la régénération, mais a aussi tué ou endommagé beaucoup d'épinettes et de pins. Le coupage des broussailes a supprimé tous les aulnes, mais la régénération a été rapide et dense, et les plants de conifères, dégagés de cette façon, ont souffert des dommages mécaniques et physiologiques. On n'a pas trouvé de témoignage d'une augmentation des taux de croissance des conifères due au dégagement des aulnes, mais on va continuer à faire des mesurages périodiques pour déterminer la croissance accrue dans l'avenir.

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RELEASING SOFTWOOD REGENERATION FROM OVERTOPPING ALDERS

by

J. Richardson

INTRODUCTION

On some forest sites in Newfoundland, a dense cover of alders (Alnus rugosa (Du Roi) Spreng. var. americana (Regel) Fern.) becomes established several years after wildfire and grows rapidly. A softwood stand can be established by seeding before the alders become a problem, but the new stand subsequently suffers severe competition from the alders. To permit unrestricted development, the softwoods must be released from the alder competition. Similar problems requiring similar solutions can arise in naturally-regenerating stands after fire. The competing species is not always alder; sometimes other hardwood species such as white birch (Betula papyrifera Marsh.), pin cherry (Prunus pensylvanica L.f.) or trembling aspen (Populus tremuloides Michx.) may cause the problem, or may be present with the alders.

In 1965 a four-year-old burned area in east-central Newfoundland was seeded from the air with a mixture of black spruce (Picea mariana (Mill.) B.S.P.) and jack pine (Pinus banksiana Lamb.). Shortly after the successful establishment of these softwood species, hardwood brush species, principally alders, began to outgrow the spruce and pine. The dense alders soon overtopped the softwoods over a considerable area, and it was decided that release treatment was required.

Following an intensive survey of the softwood regeneration and hardwood growth on the area, a study to compare the effectiveness of mechanical and chemical methods of releasing the softwoods was initiated in 1975. The preliminary effects of the treatments on the numbers of softwood and hardwood stems were observed in 1976. More detailed examinations of condition and height growth of the softwoods and hardwoods were conducted in 1977. This report describes the study and its results to date. Some of the implications for the treatment of this and related hardwood problems are discussed, and recommendations are made for future research.

DESCRIPTION OF AREA

The study is located in the North Pond forest experiment area about 32 km south of Gander, Newfoundland within Section B.28a of the Boreal Forest Region (Rowe 1972)(Figure 1). It lies on a gentle, north-facing slope at an elevation of about 105 m above sea level. Soils are well-drained stony sandy-loams derived from glacial till underlain by Devonian granitic bedrock. Soil moisture conditions throughout the area vary from fresh to moist, and the organic layer is generally no more than 3 cm deep.

Prior to 1941 the area supported a mature stand of black spruce and balsam fir (Abies balsamea (L.) Mill.) with scattered white birch and aspen. This stand was killed by wildfire in 1941. Most of the remaining merchantable fire-killed spruce and fir were salvaged in 1950. In 1961, a second fire destroyed natural regeneration and reduced the depth of organic mantle. In April 1965, the twice-burned area was broadcast seeded by helicopter with a mixture of 78 600 black spruce and 10 400 jack pine seed per ha. The seeding operation was very successful: a survey in 1970 revealed that the seeded area was 85 percent stocked to black spruce and 59 percent stocked to jack pine (by milacre quadrats) with seedling densities of 18 800 and 4 000 per ha respectively. Spruce seedlings averaged about 26 cm in height, pine seedlings 37 cm (Richardson 1973).

In the 1970 survey, no direct measurements of alders were made, but they were estimated to be about 3 m tall on average. It was clear that their rapid growth and spread were threatening the survival and growth of the softwood regeneration (Figure 2). Since 1970, the alders have continued their growth. Although alder is the most common component of the dense hardwood canopy (Figure 3) by cover and number of stems, trembling aspen, white birch and willow (Salix spp.) are also frequently present, and mountain ash (Sorbus americana Marsh.), elderberry (Sambucus pubens Michx.) and pin cherry are found occasionally.

In the absence of disturbance, the ground vegetation beneath this canopy consists of a carpet of Polytrichum and Dicranum moss which is most vigorous where the canopy is more open. Other vegetation is sparse and weak except in the open areas where ericaceous dwarf shrubs are prominent.

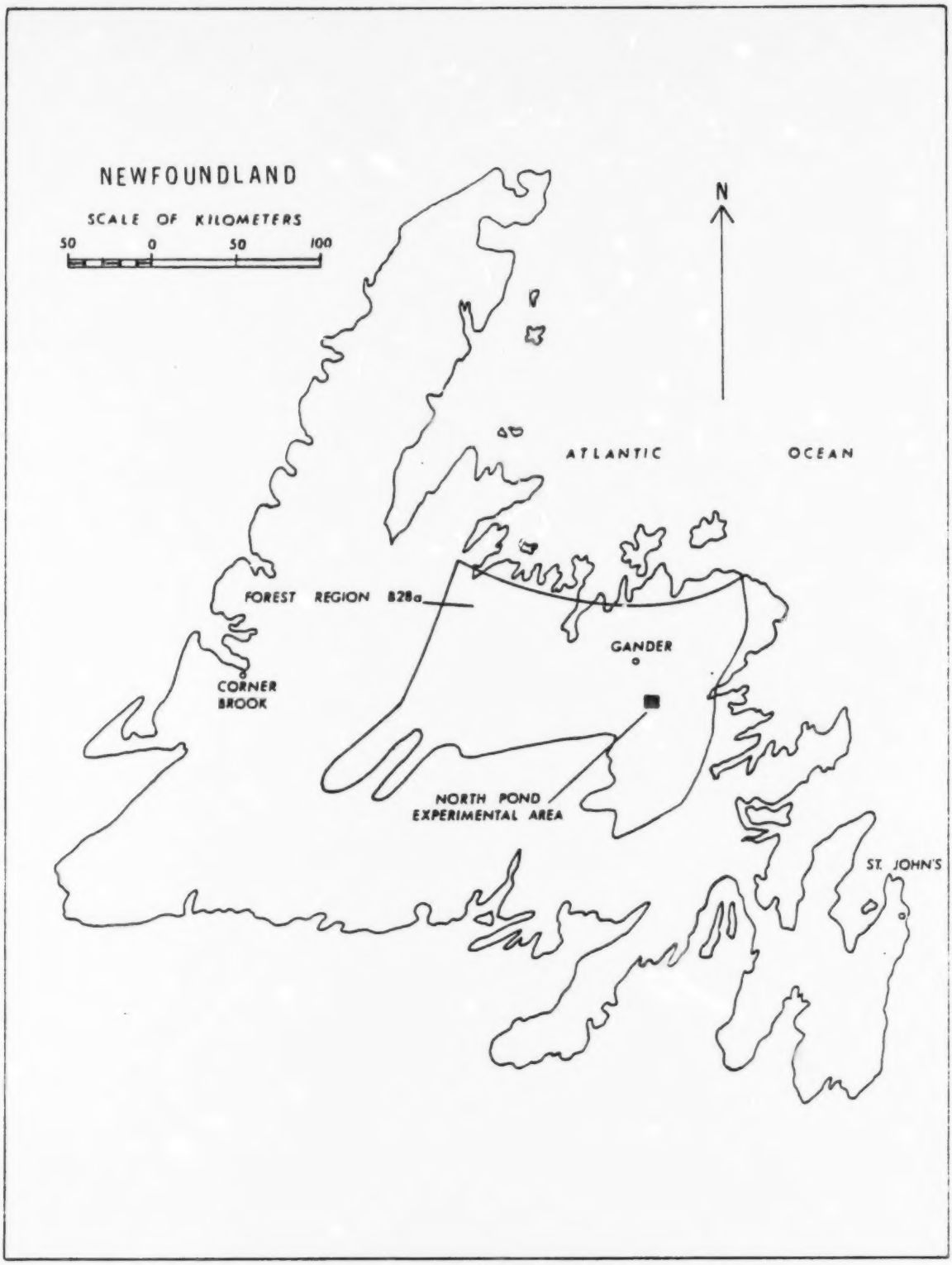

Figure 1. Location of North Pond Experimental Area

Figure 2. Suppressed browsed black spruce seedling under dense alder canopy, prior to treatment.

Figure 3. Boundary line cutting in alder control experiment, illustrating the density of hardwood, mainly alder, with some aspen.

METHODS

The experiment has a randomized complete block design with four replications of each of five treatments:

a. early application of 2,4-D
b. late application of 2,4-D
c. Tordon 10K pellet application
d. brushcutting
e. control

The systemic herbicide 2,4-D is considered to be selective, having more effect on broadleaved tree species than on conifers (Sutton 1970). However, this selectivity is at least partly related to the time of application, its effect being greatest when growth is at its peak (Sutton 1967). Two dates of application were used in this experiment to try to determine the best time for application of 2,4-D in central Newfoundland for maximum release effect with minimum damage to the softwoods. The other herbicide, Tordon, also has systemic action but is considered to be non-selective (Sutton 1970). It was hoped that Tordon pellets concentrated at the base of alder clumps would kill the alders while avoiding serious injury to the softwoods. Brushcutting was included as an alternate non-chemical release treatment, although from an operational point of view it was acknowledged to be much more costly, labour-intensive, and time-consuming than herbicide treatment (Miller 1976).

Individual treatment plots, 0.2 ha in area (50 m x 40 m), were established and boundary lines cut in 1974. Two sub-plots, each with an area of 100 m^2 (10 m x 10 m), were established at random within each plot and then subdivided into 25 quadrats each 4 m^2 (2 m x 2 m). In order to reduce edge effects, no sub-plot was located closer than 2 m from a plot boundary.

In spring 1975 a pre-treatment survey of the softwood regeneration and the hardwood canopy was conducted. On each quadrat the following information was recorded: number and condition of spruce and pine seedlings; total height and 1974 leader length of the tallest spruce and pine; average height and cover (in tenths) of the hardwoods; and number of live stems of each hardwood brush species. For alder clumps and bushy species, stems were counted at 15 cm above ground level.

The early application of 2,4-D was made on 8-9 July 1975 using 1.1 kg acid equivalent per ha of the amine formulation in about 400 ℓ per ha of water. The 2,4-D was applied to each plot in a series of strips using a portable backpack-type mist blower (Figure 4). Spraying was carried out under calm or light wind conditions in the early morning

Figure 4. Application of 2,4-D by backpack mistblower.

to lessen the risk of spray drift. Rainfall was negligible at nearby Gander International Airport for four days prior to spraying, traces of rain were recorded during the two days of spraying, and only 0.30 cm of rain fell during the following week. Temperatures were high on the days of spraying (22-27°C) and even higher during the following week (up to 30°C).

The late application of 2,4-D was made on 6-7 August 1975 using the same rates of application and techniques as earlier. Only 0.10 cm of rain fell during the five days prior to spraying, a trace of rain was recorded on the second day of spraying, and thereafter only traces until 13 August when 1.73 cm of rain fell. Temperatures were warm on the first day of spraying (24°C), cooler the second day (18°C), and warm again during the following week (up to 29°C).

On July 3-4, 1975, Tordon 10K pellets containing 10 percent acid equivalent of the potassium salt of 4-amino-3,5,6-trichloropicolinic acid (picloram) were applied at the rate of 40 kg per ha. The pellets were spread by hand, concentrating them on the alder clumps. Only 0.17 cm rain was recorded during the week prior to application, 1.47 cm during the two days of application and only traces of rain during the following week. Temperatures were warm (22-28°C) throughout this period.

Brushcutting was carried out between late August and October 1975. A portable motorized brushcutter and axes were used to cut all hardwood stems close to ground level. The cut stems were generally left where they fell, but care was taken to avoid damage to the taller softwoods. Some softwood stems were cut accidentally with the brushcutter, but the damage from this cause was not excessive.

Periodic general observations of the effects of the herbicides were made for several months after application in 1975. In May 1976 a survey was conducted to determine the immediate effects of the treatments on the softwood regeneration. On each quadrat in each sub-plot the following information was recorded: number of live undamaged; live damaged; and dead spruce and pine; and condition of the live damaged seedlings.

This was followed in August 1976 by a survey to determine the effects of the treatments on the hardwoods after one year. On each quadrat, a count was made of the number of live and dead stems of each hardwood species. In addition, an estimate was made of the total hardwood cover on each quadrat.

In August-September 1977, two years after treatment, a complete remeasurement of the experiment was conducted. On each quadrat the following information was recorded: number and condition of spruce and pine seedlings; total height and leader length of the tallest spruce

and pine; average height and cover of the hardwoods; and number and condition of live stems of each hardwood brush species. An attempt was made to distinguish between new hardwood stems originating since treatment, and older stems. Notes were also made of the ground vegetation in each quadrat.

Data from each examination were compiled, tabulated, and subjected to analysis of variance in accordance with standard statistical procedures. Differences between means were tested for significance using Duncan's new multiple range test (Steel and Torrie 1960).

RESULTS

a. Softwood regeneration

Percent stocking and stem density of black spruce and jack pine prior to treatment, and one and two years after treatment are shown in Table 1. Black spruce stocking and density were high both before and after treatment. No significant differences were found among treatments or blocks with respect to these two factors either before or after treatment. Black spruce stocking was relatively unchanged following treatment, but density decreased after all but the late 2,4-D treatment. The greatest decreases (5-6000 stems/ha after two years) were recorded after Tordon application and brushcutting. Except in the case of the control, most of the change in density took place within one year of treatment.

A moderate stocking of jack pine was present on most of the area before treatment. Significant differences in stocking existed, with Blocks I and II having a higher stocking than Blocks III and IV. Stocking did not change appreciably after treatment, except in the case of Tordon application which reduced stocking after two years to less than 25 percent of its pre-treatment level. However, because of the considerable variation among individual plots, none of the differences in jack pine stocking among treatments were significant either before or after treatment. Trends in jack pine density generally paralleled those in stocking, again without significant differences between treatments. Slight decreases in density were recorded in most treatments, including control, between 1975 and 1977. The decreases were evenly divided between 1975-76 and 1976-77 except after late 2,4-D application where there was no decrease till the second year after treatment. A major decrease in density was recorded after Tordon treatment. Stocking and density relationships among blocks did not change appreciably as a result of treatment.

Table 1.- Stocking and density of spruce and pine regeneration before and after treatment.

	Date of examination					
	Prior to treatment (June 1975)		1 year after treatment (May 1976)		2 years after treatment (Aug.-Sept.1977)	
	% stocking	Stems/ha	% stocking	Stems/ha	% stocking	Stems/ha
Black spruce						
Treatment -						
Brushcutting	86 a*	18253 c	86 e	12738 g	88 i	12775 k
Early 2,4-D	94 a	20130 c	95 e	16062 g	94 i	15894 k
Late 2,4-D	94 a	16154 c	94 e	19525 g	95 i	18611 k
Tordon	92 a	17055 c	90 e	11638 g	86 i	10139 k
Control	98 a	23391 c	99 e	21100 g	99 i	18698 k
Block -						
I	90 b	17191 d	90 f	16620 h	88 j	15067 ℓ
II	96 b	23090 d	96 f	18350 h	95 j	16519 ℓ
III	93 b	16974 d	88 f	13940 h	90 j	12953 ℓ
IV	97 b	18732 d	96 f	15940 h	96 j	16351 ℓ
Average	94	18997	93	16212	92	15223
Jack pine						
Treatment -						
Brushcutting	28 m	1754 q	24 t	1462 w	22 z	1186 B
Early 2,4-D	42 m	3359 q	46 t	2825 w	46 z	2594 B
Late 2,4-D	42 m	3124 q	42 t	3262 w	37 z	2890 B
Tordon	54 m	3594 q	40 t	1862 w	13 z	457 B
Control	53 m	4298 q	54 t	3712 w	49 z	2915 B
Block -						
I	65 n	4545 rs	64 u	4280 xy	55 A	3665 C
II	59 n	4624 r	60 u	3900 xy	43 A	2529 C
III	36 np	2638 rs	35 uv	2050 x	31 A	1689 CD
IV	15 p	1097 s	7 v	250 y	5 B	148 D
Average	44	3226	41	2622	33	2008

*Means followed by the same letter are not significantly different (5% level)

Average height and leader length of black spruce and jack pine prior to treatment and two years after treatment are shown in Table 2. Average black spruce height before treatment was 120 cm; three growing seasons later, and two years after treatment it was 150 cm. There were no significant differences in black spruce height or leader length among treatments either before or after treatment. Average black spruce height increased most after the 2,4-D applications (36-38 cm) and in the control plots (39.5 cm). There was hardly any increase (3.0 cm) after Tordon application, although the average leader length recorded two years after Tordon application (12.5 cm) was about the same as before treatment (12.8 cm). Black spruce leader length was slightly greater after 2,4-D application (1.8-4.7 cm) and in control plots (2.0 cm), but was less after brushcutting (1.7 cm).

There were significant differences in black spruce average height among blocks before treatment, with average height decreasing from Block II, through Blocks I and III, to Block IV. This trend was still present two years after treatment but differences were no longer significant. A similar trend existed in black spruce leader length before and after treatment.

On average, jack pine height was almost exactly the same as that of black spruce - 121 cm before treatment, 151 cm two years after treatment. There were no significant differences in jack pine height or leader length among treatments either before or after treatment. However, there were some considerable but non-significant differences before treatment which were maintained to some extent after treatment. Average jack pine height increased most after brushcutting (53.5 cm) and the early 2,4-D application (50.3 cm); it increased less after late 2,4-D application (23.0 cm) and in the control plots (37.1 cm), and there was a net decrease after Tordon application (6.1 cm). Jack pine leader length was greater in 1977 than in 1974 only in the control plots (1.5 cm). It was unchanged after early 2,4-D application, there were slight net decreases after brushcutting (2.6 cm) and late 2,4-D application (5.3 cm), and it was considerably less after Tordon application (17.1 cm).

There were significant differences in jack pine average height among blocks before and after treatment. Average height in Block IV was much less than in the other blocks. Between 1975 and 1977 average height decreased appreciably in Block IV, remained about the same in Block II, and increased considerably in Blocks I and III. On average, jack pine leader length decreased slightly between 1975 and 1977. The decrease was greatest in the blocks (I and III) in which leader length was greatest in 1975; in the other two blocks, leader length increased slightly.

Table 2.- Average height and leader length of spruce and pine regeneration before and after treatment.

	Date of examination			
	Prior to treatment (June 1975)		2 years after treatment (Aug.-Sept. 1977)	
	Av. ht. tallest stem/quad (cm)	Av. 1974 leader on tallest stem/quad (cm)	Av. ht. tallest stem/quad (cm)	Av. 1977 leader on tallest stem/quad (cm)
Black spruce				
Treatment -				
Brushcutting	135.4 a*	14.5 d	156.8 h	12.8 j
Early 2,4-D	114.5 a	14.4 d	152.6 h	19.1 j
Late 2,4-D	118.2 a	15.2 d	154.5 h	17.0 j
Tordon	102.8 a	12.8 d	105.8 h	12.5 j
Control	137.0 a	17.1 d	176.5 h	19.1 j
Block -				
I	129.2 bc	18.0 ef	173.5 i	18.2 kr
II	162.3 b	20.6 e	199.4 i	20.4 r
III	107.3 bc	12.1 fg	131.8 i	14.0 kr
IV	83.0 c	8.2 g	97.5 i	12.4 k
Average	120.3	14.7	150.2	16.2
Jack pine				
Treatment -				
Brushcutting	140.8 ℓ	23.4 p	194.3 r	20.8 u
Early 2,4-D	153.8 ℓ	25.2 p	204.1 r	25.2 u
Late 2,4-D	89.6 ℓ	18.9 p	112.6 r	13.6 u
Tordon	154.9 ℓ	25.9 p	148.8 r	8.8 u
Control	74.0 ℓ	14.0 p	111.1 r	15.5 u
Block -				
I	119.5 m	24.1 q	168.8 s	19.0 v
II	143.1 m	23.3 q	141.5 s	16.1 vw
III	107.0 mn	17.9 q	146.3 s	19.4 vw
IV e	75.2 n	9.3 q	57.5 t	12.5 w
Average	121.0	21.3	150.8	17.9

*Means followed by the same letter are not significantly different (5% level)

Prior to treatment many of the softwood seedlings showed signs of suppression: 66 percent of all quadrats contained suppressed black spruce, and 61 percent contained suppressed jack pine. Twisted, forked and etiolated stems were also common and 10-20 percent of all quadrats contained seedlings browsed by rabbits or moose (Figure 2).

All treatments caused some damage to the softwood regeneration. One year after treatment, winter damage (mostly needle reddening) affected black spruce and jack pine in 25 and 42 percent, respectively, of brushcut quadrats. Some black spruce seedlings were covered by brush (Figures 5, 6) in 37 percent of brushcut quadrats and brushcutter damage was found on black spruce in 14 percent of quadrats. Both applications of 2,4-D caused needle discoloration, loss of foliage and damage to leaders, affecting pine seedlings more than spruce. Tordon caused more damage to softwoods than any other treatment. Dead spruce were found in 54 percent of Tordon-treated quadrats and dead pine in 58 percent. Needle discoloration of spruce and pine was present in 42 and 56 percent, respectively, of Tordon-treated quadrats. The figures for damaged leaders (Figure 7) were 49 percent for spruce and 17 percent for pine. Healthy spruce were found in only 74 percent of Tordon-treated quadrats compared with 100 percent of control quadrats; corresponding figures for pine were 19 and 34 percent.

Two years after treatment, the signs of damage were less widespread. Most damage was still found in Tordon-treated quadrats where healthy spruce were evident in only 56 percent compared with 84 percent of control quadrats; corresponding figures for pine were 23 and 52 percent. Pine seedlings with dead tops were found in 54 percent of Tordon-treated quadrats, spruce with dead tops in 9 percent. Spruce with dead tops were not found elsewhere. Healthy spruce were found in 79-80 percent of 2,4-D treated quadrats. Jack pine was much less frequently browsed in treated plots (4-22 percent) than in control plots. Spruce budworm (Choristoneura fumiferana Clemens) damage was found on black spruce only in brushcut plots (7 percent of treated quadrats contained damaged spruce).

b. Hardwoods

The cover and height of hardwoods before and after treatment are shown in Table 3. Prior to treatment there were significant differences in hardwood cover among blocks, with a trend of increasing cover from Block I to Block IV. Cover was reduced after all treatments, including control plots, with greatest reduction in plots treated with Tordon. Hardwood cover was slightly greater after application of 2,4-D than after brushcutting. Maximum reduction in cover took place within one year after treatment, with a further slight reduction the following year. The differences among blocks were lessened after treatment.

Figure 5. Brushcutting plot immediately after treatment. Note abundance of cut brush.

Figure 6. Brushcutting plot, one year after treatment. Note reduction in volume of brush, and release growth on black spruce in foreground.

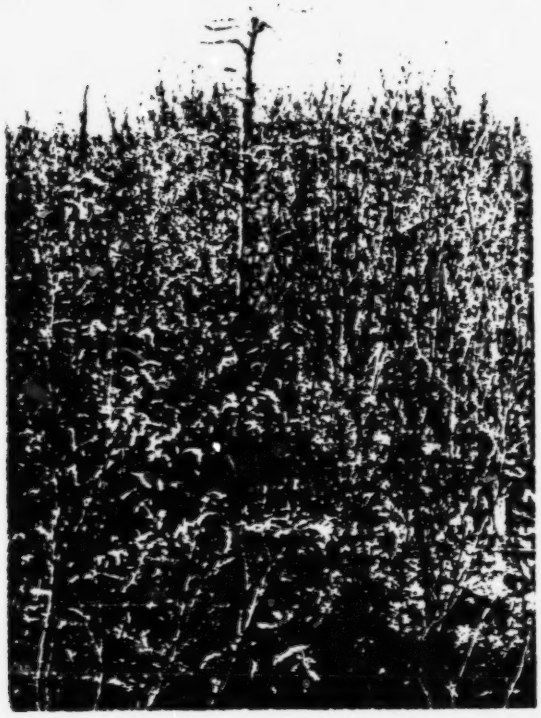

Figure 7. Twisting of new growth on black spruce one year after Tordon treatment. Photo taken in spring before bud burst.

Table 3. Cover and height of hardwoods before and after treatment.

	Hardwood cover (tenths)			Avg. height of hardwoods (m		
	Prior to treatment (June 1975)	1 year after treatment (Aug. 1976)	2 years after treatment (Aug.-Sept. 1977)	Prior to treatment (June 1975)	2 years after treatment (Aug.-Sept. 1977)	
					Old stems	New stems
Treatment -						
Brushcutting	7.1 a*	3.1 d	2.6 g	2.52	1.92	0.86
Early 2,4-D	6.8 a	3.6 d	3.1 gh	2.17	2.67	0.58
Late 2,4-D	6.4 a	3.7 d	2.9 g	2.53	2.66	0.53
Tordon	7.2 a	2.1 d	1.4 g	2.07	1.82	0.45
Control	7.2 a	6.5 e	4.9 h	2.25	2.93	0.56
Block -						
I	5.6 b	3.1 f	2.6 i	1.60	1.74	0.53
II	7.0 bc	4.0 f	3.1 i	2.02	2.26	0.58
III	7.4 c	3.7 f	2.8 i	2.40	2.54	0.64
IV	7.9 c	4.4 f	3.4 i	3.21	3.82	0.69
Average	7.0	3.8	3.0	2.31	2.56	0.61

*Means followed by the same letter are not significantly different (1% level).

Before treatment, average hardwood height (2.31 m) was almost double the average softwood height (1.20-1.21 m, Table 2). There was a trend of increasing hardwood height from Block I to Block IV. The average height of surviving stems two years after treatment was less than before treatment in brushcutting and Tordon plots, it was slightly more than before in 2,4-D-treated plots, and 33 percent taller than before in control plots. New stems originating after treatment reached 0.5 m in most treatment plots by 1977 and 0.86 m in brushcut plots. New stems showed the same height gradation from Block I to Block IV as shown by the original hardwoods.

Table 4 shows the number of alder stems and the total number of hardwood stems of all species before and after treatment. Prior to treatment the average hardwood density (64 222 stems/ha) was almost three times as great as that of spruce and pine combined (Table 1). Alders accounted for 72 percent of the total, occurring mostly in clumps of 10 or more stems.

Table 4.- Numbers of alders and total hardwood stems before and after treatment.

	Number of live stems/ha							
	Alders				Total hardwoods			
	Prior to treatment (June 1975)	1 year after treatment (Aug. 1976)	2 years after treatment (Aug-Sept 1977)		Prior to treatment (June 1975)	1 year after treatment (Aug 1976)	2 years after treatment (Aug-Sept 1977)	
Treatment -			Old stems	Old + new			Old stems	Old + new
Brushcutting	42749 a*	23550 c	333 f	37544 j	56525 m	53612 o	963 r	70742 u
Early 2,4-D	46332 a	23450 c	16833 h	30183 j	65050 m	31875 op	23564 s	41125 uv
Late 2,4-D	44973 a	27050 c	20242 h	39841 j	59305 m	34575 o	24985 s	49710 uv
Tordon	49606 a	8212 d	8262 g	17574 k	72031 m	9788 p	9917 r	19773 v
Control	47691 a	34925 c	31789 h	40446 j	68201 m	50462 o	44016 s	53650 u
Block -								
I	45022 b	18180 e	14751 i	33770 ℓ	71117 n	25990 q	20423 t	43849 w
II	42798 b	26430 e	16104 i	31408 ℓ	64544 n	45790 q	24216 t	49084 w
III	45566 b	20850 e	13437 i	28366 ℓ	60689 n	32760 q	17360 t	43000 w
IV	51694 b	28290 e	17675 i	38927 ℓ	60540 n	39710 q	20757 t	52067 w
Average	46270	23438	15492	33118	64222	36062	20689	46999

*Means followed by the same letter are not significantly different (1% level).

One year after treatment the number of live alders had been reduced in all plots. Tordon caused the greatest reduction (83 percent) in numbers of live alders. The 1976 survey did not distinguish between old and new hardwood stems, but the 1977 survey showed that a considerable number of new alder stems had sprouted since treatment. In brushcutting plots almost all original alders had been cut, but nearly as many new stems had appeared. In herbicide-treated plots the number of new alder stems was approximately equal to the number of old stems. However, two years after treatment, the number of live alder stems in Tordon-treated plots was only 34 percent of the total before treatment.

Numbers of other hardwood species were also reduced after treatment, especially after brushcutting and Tordon application. However, many new stems appeared after treatment, particularly in the brushcutting plots where the total number of hardwood stems two years after treatment exceeded the number of stems before treatment by 25 percent despite the fact that almost all hardwood stems were cut. Tordon-treated plots had fewest hardwood stems two years after treatment. There were slightly fewer hardwood stems in plots to which 2,4-D was applied early than in plots to which it was applied late.

There were no significant differences in numbers of live alder stems or total live hardwood stems among blocks either before or after treatment.

The numbers of stems of hardwood species other than alders before and after treatment are shown in Table 5. Four species are involved - trembling aspen, willow, white birch and pin cherry - of which aspen and willow were most common before treatment. However, neither aspen nor willow had more than 20 percent as many stems as alders.

Brushcutting virtually eliminated all hardwood stems, but one year after cutting all four species were denser than before treatment. The increase ranged from about 40 percent for aspen to over 1000 percent for cherry. One year after 2,4-D treatment numbers of stems of most species were reduced by about half. Early application of 2,4-D had a greater effect on willow than late application. Two years after 2,4-D treatment, numbers of stems were still less than before treatment except in the case of cherry. Willow numbers had increased slightly from 1976 but aspen and birch numbers remained about the same or less than in 1976. One year after Tordon treatment, numbers of stems of all four species were reduced to less than 10 percent of their pre-treatment level. Birch and cherry numbers increased slightly the following year but aspen and willow numbers remained about the same. On the control plots, numbers of aspen, willow and birch tended to decrease from 1975 to 1977, but numbers of cherry stems increased. On average aspen and birch numbers decreased from 1975 to 1977, willow numbers remained the same, and cherry increased.

Table 5. Numbers of aspen, willow, birch and cherry stems before and after treatment.

Species	Date	Treatment					Block				Average
		Brush-cutting	Early 2,4-D	Late 2,4-D	Tordon	Control	I	II	III	IV	
Aspen	June 1975	6610	9514	6672	10749	10317	11861	11910	7413	3904	8772
	Aug. 1976	9162	5362	3175	1012	7325	3740	7590	4630	4870	5208
	Aug. 1977										
	Old stems	445	5088	2705	1161	6422	3310	5365	2411	1571	3164
	Old + new	7101	5360	2976	1358	6484	3903	6047	4081	4594	4656
Willow	June 1975	6486	8278	6610	10131	9452	12998	8451	7314	4003	8191
	Aug. 1976	18212	2688	4188	525	7438	3550	11420	5250	6220	6610
	Aug. 1977										
	Old stems	173	1346	1927	408	5175	2233	2648	1205	1136	1806
	Old + new	22440	4816	6002	543	5792	5553	11293	7321	7509	7919
Birch	June 1975	161	309	111	531	358	464	445	178	89	294
	Aug. 1976	375	100	0	38	112	130	190	150	30	125
	Aug. 1977										
	Old stems	12	25	0	74	74	30	30	30	0	22
	Old + new	704	25	12	185	136	217	99	464	0	195
Cherry	June 1975	222	543	358	272	457	652	128	148	553	370
	Aug. 1976	2312	275	162	0	662	390	160	1880	300	682
	Aug. 1977										
	Old stems	0	272	111	12	556	99	69	277	375	205
	Old + new	2952	741	877	111	790	405	237	2766	1037	1111

c. Ground Vegetation

Prior to treatment the ground layer beneath the hardwood canopy consisted generally of a carpet of Polytrichum and Dicranum moss, with occasional sparse and weak Rubus and Kalmia. In the open areas where the hardwood canopy was incomplete, ericaceous dwarf shrubs were vigorous and predominant.

Two years after treatment the ground layer on the herbicide-treated plots was dominated by grasses, chiefly Calamagrostis. The grass cover was densest and most vigorous on the Tordon-treated plots, especially those which had the densest hardwood canopy before treatment. Raspberry (Rubus sp.) also flourished on the plots where the greatest canopy reduction had taken place. On the brushcut plots some expansion of the ericaceous dwarf shrub cover and an increase in its vigour were observed.

DISCUSSION

The objective of applying treatments in this experiment was to release the softwood regeneration from the overtopping hardwoods. All treatments accomplished this in the first year after application. Hardwood cover was reduced and the numbers of stems of all species of hardwoods were considerably reduced. Few, if any, hardwoods escaped the saw in the brushcut plots. The non-selective herbicide, Tordon, was almost equally effective. The selective herbicide, 2,4-D, did not produce such dramatic results but the early application appeared slightly more effective than the late application.

The reduction in hardwood cover and numbers of stems was largely transitory, however. The increased light caused by the reduction in hardwood cover stimulated a rapid regrowth of hardwoods within one year after treatment. Sprouting was particulary prevalent after brushcutting. The chemical treatments seemed to delay or inhibit sprouting to some extent, or perhaps there was less light under the partially-opened herbicide-treated hardwood canopy than in the completely open brushcut plots. Tordon seemed to control regrowth longer than the other treatments. Willow and cherry, both pioneer shrubs, sprouted more profusely than other species, while birch and aspen, the only species capable of reaching tree size, sprouted less than other species.

Two years after treatment the numbers of hardwood stems approached pre-treatment levels and in the case of brushcutting had already passed that level. Although the new sprouts were still much

smaller than the average height of the dominant softwood stems, their rapid growth still gives cause for concern. On brushcut plots, sprouts appeared in very high numbers and grew faster than elsewhere, so that brushcutting does not appear to be a satisfactory method of release.

None of the treatments had any statistically significant effect on the stocking, density, height or leader length of either softwood species. Thus, from a statistical standpoint, the treatments had no adverse effect on the spruce and pine. On the other hand, there was no statistically significant beneficial effect of increased growth as a result of treatment either. The lack of statistical significance is due to the large variation within treatments.

The absence of any clear sign of softwood release growth after treatment may be due to the short period between treatment in 1975 and the remeasurement in 1977. For this reason, it is recommended that the softwood growth be remeasured in 1979, and perhaps in subsequent years also. Casual observations in the fall of 1978 suggested that softwood growth rates may have increased appreciably since 1977.

Brushcutting caused mechanical damage to softwoods both as a result of the saw blade accidentally touching softwood stems, and due to cut brush covering small seedlings. The larger spruce and pine, suddenly and completely released by this drastic treatment from years of surviving in or under protecting hardwood canopy, suffered considerable winter drying damage during the first year after treatment. The spruce were opened up sufficiently by brushcutting that spruce budworm damage occurred, though such damage was not apparent in other treatments. Thus, from a silvicultural viewpoint, brushcutting does not appear to be a satisfactory treatment. Moreover, it is much more labour-intensive than the herbicide treatments: it took two men approximately two months to complete the brushcutting treatment; each herbicide treatment took two men no more than eight hours to apply. Under operational conditions, with aerial application of herbicide, brushcutting could be expected to cost up to eight times as much as herbicide application. Brushcutting is recommended only for areas where, for environmental reasons, herbicides are unacceptable, or where a labour-intensive treatment is desired.

Of the herbicide treatments, Tordon had the greatest adverse effect on the softwoods. It killed many spruce and pine, and caused needle discoloration and damaged leaders on many others. Its undesirable effects have persisted longer than those of other treatments with little sign of recovery. It is possible that a lower rate of application might cause less damage. As discussed earlier the objective in using this non-selective herbicide was to determine whether, by selective application of the herbicide pellets, damage to softwoods could be minimized while achieving a satisfactory kill of alders. This objective was not achieved and, in fact, the effects of this treatment were observed to have moved, presumably through the soil, outside the

boundaries of the Tordon-treated plots. Use of Tordon at the rates applied here to release softwood regeneration from a hardwood overstory is not recommended. However, because of its ease of application by hand and its profound effect on hardwood species, it may find use where eradication of hardwoods is desired on limited areas prior to reforestation.

The selective herbicide 2,4-D produced the most satisfactory results. It reduced the hardwood numbers and cover while causing a minimum of damage to the spruce and pine seedlings. Both softwood species suffered some needle discoloration, loss of foliage and leader damage as a result of 2,4-D application, but the extent and degree of damage were less than that with brushcutting and much less than that with Tordon. Because 2,4-D did not completely remove the hardwood canopy, it is likely that regrowth of hardwoods will be less prevalent and slower than in the other treatments. This is true already for the comparison with brushcutting. The difference between the effects of early and late application of 2,4-D is minimal.

The changes in ground vegetation following treatment may have important implications for future softwood growth. The dense growth of grass and raspberry on some plots may have as detrimental an effect on the growth of the smaller softwood seedlings as the hardwood canopy had. On other plots, expansion of Kalmia cover may have a similar inhibiting effect on growth of smaller softwood seedlings.

The slight but regular decrease in hardwood cover and numbers of all hardwood species, except cherry, on control plots is somewhat difficult to explain. It is possible that the plots were too small and that the general disturbance caused by plot-boundary cutting and the treatments may have caused some hardwood mortality in control plots. This argument is supported by the fact that half of the control subplots were located next to a plot boundary. However, comparison of data from subplots next to the border with data from subplots in the centre of control plots showed no appreciable difference in number of hardwood stems or cover either before or after treatment. Since there is also a parallel slight decrease in softwood densities on control plots, another explanation may be the accidental destruction of some small seedlings (or hardwood sprouts) during subplot measurement. Some of the subplots had a great many small weak seedlings and the destruction of about one black spruce and seven hardwood stems per quadrat does not appear implausible.

Although the particular situation (twice-burned cutover, artificially seeded) in which this experiment was conducted is somewhat unusual, the results do have some application elsewhere. On most burned or cutover sites in central Newfoundland on which alders cause a regeneration problem the softwood regeneration on the site is inadequate or

absent, and hardwood eradication followed by reforestation is indicated. However, on other sites, hardwoods such as white birch and pin cherry compete strongly with softwood regeneration which is of adequate stocking and density. On such sites, releasing the softwoods from the hardwood competition may be desirable, and the results of this experiment show that application of 2,4-D may have the desired effect.

CONCLUSIONS

The effects of three herbicide treatments and brushcutting used as means of releasing softwood regeneration from overtopping alders and other hardwood species have been examined two growing seasons after treatment. The following conclusions may be made about the treatments:

- Brushcutting removed virtually all existing hardwood stems but was followed by a rapid dense regrowth; spruce and pine seedlings thus released suffered mechanical damage and physiological shock causing a decrease in seedling density.

- Tordon, a non-selective herbicide applied in pellet form to the soil, killed most hardwood stems and inhibited regrowth; it caused considerable mortality and damage to spruce and pine seedlings; and its effects spread beyond the boundaries of the areas to which it was applied.

- 2,4-D, a selective herbicide applied in water to foliage by mist-blower, caused a reduction in hardwood numbers and cover, less than that caused by brushcutting and Tordon, and was followed by some regrowth, less than that following brushcutting; it caused some damage to spruce and pine seedlings, but less than that caused by Tordon.

- Applying 2,4-D in early July was not clearly superior to applying it in early August.

- For the period of observation reported here, there is no evidence of increased softwood growth rates due to release from the hardwood overstory.

The best results in this experiment, in terms of maximum control of the hardwoods with minimum regrowth and minimum damage to the softwood regeneration, was achieved by the 2,4-D treatments. This treatment is suitable for large-scale application from aircraft.

The absence in the reported results of any evidence of release growth of softwoods due to the treatments leads to a recommendation that periodic remeasurements be continued to determine if such release will become evident later.

Although the particular site and stand conditions in which this experiment was conducted — an artificially seeded stand of black spruce and jack pine under overtopping alders and other hardwoods on a twice-burned site — is unique in Newfoundland, the results are certainly applicable to the widespread problem of hardwood competition to softwood regeneration on burned sites and cutovers in central Newfoundland. Some of the results may also have application to the related problem of sites requiring hardwood eradication prior to reforestation.

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